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Technical Efficiency of Onion Production among Smallholder Farmers in Wukari Local Government Area, Taraba State, Nigeria

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Onion (*Allium cepa* L.) is an important vegetable crop widely used as a condiment. Globally, China and India dominate production, while Nigeria ranks 16th with an annual output of 1.40 million metric tons (1.43% of global production). This study analyzed the technical efficiency of onion production in Wukari Local Government Area of Taraba State, Nigeria. The study used snowballing to obtained the sample frame and simple random sampling techniques to select primary data from 178 onion farmers during the 2023 farming season. Descriptive statistics and the Cobb-Douglas stochastic frontier production function were used to analyzed the data. The average onion output of the survey farms was 5,282 kg/ha. On average, the quantity of seed used was 4.7 kg/ha, fertilizer 216 kg/ha, agrochemicals 1.2 liters per hectare (l/ha), and labour work was 48 man-days per hectare, respectively. The mean age and household size of the farmers were 41 years and 8 persons, respectively. The majority (78.7%) of the respondents had some form of formal education, and the average farming experience of the farmers was 15.7 years. An estimate of the Cobb-Douglas production function shows that the average technical efficiency of the farmers stood at 86% (0.8609), with a minimum of 50% (0.5066) and a maximum of 98% (0.985), respectively. The inefficiency model shows that household size, education level and farming experience are factors that significantly reduce technical inefficiency. The study concludes that onion producers in the study area were technically efficient but below the frontier level. To boost the output of onion production, the study recommends that government and non-governmental organizations should subsidize the cost of farming inputs, farmers should be encouraged to improve educational attainment., and they should utilize their extensive experience to involve family members in onion farming to mitigate the high costs associated with hired labour.
Keywords: Onion production, small-scale farmers, low productivity, technical efficiency, extension services, snowballing.

INTRODUCTION

Onion (*Allium cepa* L.) is a vital vegetable crop widely used as a condiment and a low-cost source of micronutrients for health, particularly in Sub-Saharan Africa (Olanrewaju et al., 2021; Osei et al., 2017; Robert et al., 2021). Globally, dry onion production averaged 89.18 million tons annually between 2010 and 2018 (Food and Agriculture Organization, FAO, 2020). While China, India, and the United States are major producers, Nigeria holds the 16th position worldwide, contributing 1.40 million metric tons (1.43%) to global production (FAO, 2020). Onion, along with other vegetables like tomatoes, okra, pepper, and cabbage, is widely cultivated by small-scale farmers along riverbanks that span various villages, towns, and cities (Robert et al., 2021). This practice has been used for decades in Nigeria, particularly in Taraba State, to provide employment and income to farmers, particularly during the long dry season.

Despite the economic importance of onions, in Taraba State, its production has been observed with fluctuating output. The state encountered a boom in 2017, when output remained at 323 thousand tons. During this time, the area of land used was 63 thousand hectares, while the average yield per hectare was 5.13 tons (Table 1). In 2018, the output declined to 126 thousand tons and the average yield declined to 1.62 tons per hectare, while the area under cultivation increased to 78 thousand hectares. Although in 2019, the output increased to 376 thousand tons, the average yield increased to 6.59 tons per hectare, and the area under cultivation declined to 57 thousand hectares. However, in 2020, the output declined to 276 thousand tons, average yield also declined to 4.18 tons per hectare while the area under cultivation increased to 66

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thousand hectares (Taraba Agricultural Development Programme, 2021).

Table 1. The trend of onion production in Taraba State.

S/N	Year	Area harvested (ha)	Yield (tonnes)	Production (mt)
1	2017	63,000	5.13	323,000
2	2018	78,000	1.62	126,000
3	2019	57,000	6.59	376,000
4	2020	66,000	4.18	276,000

Source: TADP, 2021.

In Wukari Local Government Area (LGA) of Taraba State, onion cultivation is generally done with manual labour tools such as cutlasses, hoes, and irrigation boxes for farm irrigation. Low productivity and significant underutilization of available resources characterize this approach. Because onions are highly perishable, they are extremely sensitive to heat and humidity, and due to lack of storage facilities and poor road networks, farmers are compelled to sell their crops at the farm gate for a low price. Studies have indicated that onion farmers struggle to obtain subsidized farm inputs such as improved seeds, fertilizer, herbicide, financing, and extension services, and that even when these inputs are available, most farmers may not use them appropriately. Environmental issues such as pest and disease outbreaks, drought, and flooding all have an impact on onion producers' capacity to produce a high yield. Every farmer's goal is to use input elements to achieve the highest and most achievable yield. Large variation between observed yield and maximum achievable yield are therefore undesirable. As a result, studying technical efficiency is one method of maximizing yield. While several studies have explored onion productivity in Nigeria, limited attention has been given to technical efficiency estimation in Taraba State using a stochastic frontier approach. The purpose of this research was to establish the technical efficiency of onion production in the Wukari Local Government Area of Taraba State, Nigeria.

Conceptual framework**:** The main focus of this research is the question of whether the efficiency of onion production in Wukari Local Government Area, socio-economic and technological factors lead to problems of output variability, and if so, what possible measures should be taken. The study conceptualizes the relationship between what a farmer can produce (mean output) and what could be feasibly produced (frontier output) under the assumption of full utilization of resources and defined technology. What a farmer can produce could be influenced by factors such as land, seeds, fertilizer, agrochemicals, and labour. The study further assumed that the difference between the output of the farmers (mean output) and what they could possibly produce (frontier output) is a measure of inefficiency and that the inefficiency of the farmers could be reduced by their socioeconomic factors. These assumptions are consistent with Kara et al. (2019).

MATERIALS AND METHODS

The study area**:** The study was conducted in Wukari Local Government Area (LGA) of Taraba State, Nigeria. Taraba State covers a land mass of 59, 400km^2 with sixteen LGA's. Wukari LGA lies approximately between latitude 7^0 52'17.00 North of the equator and longitude 9^{0}46'40.30" East of the Greenwich meridian. It covers an area of approximately 4,308 square kilometers (1,663 sq mi) and has a projected population of about 328,146 as at December, 2016 with ten wards (National Population Commission, 2006). The LGA shares boundaries with Ibi LGA to the North-West, Donga LGA to the North- East and Ukum LGA of Benue State to the South-East (TADP, 2021).

Wukari LGA has a tropical climate characterized by both dry and wet seasons. The dry season commence around November and ends in March. It has an average annual rainfall of 1200-1800mm with an average temperature of 20^{o}C. Soil type and hydrology allow for cultivation of crops like yam, cassava, groundnut, cowpea, maize, millet, rice, onion, okra, pepper, tomatoes, and vegetables in large quantities in the dry season. Moreover, the people in the region rear large number of animals like cattle, sheep and goat beside engaging in poultry, and rabbit production to supplement their incomes (Oruonye & Bashir, 2011). The local government area is blessed with agricultural land and some rivers (River Benue and River Donga) where vegetables like okra, spinach, pepper and tomatoes are mostly cultivated during dry season.

Methods of data collection**:** During the 2023 farming season, primary data were obtained from respondents using a structured questionnaire. The questionnaire included socioeconomic information from farmers such as age, marital status, educational level, farming experience, family size, and access to extension services. The questionnaire also included input-output data such as the amount and cost of various onion production inputs, the amount of output received, and the price of output. Other information includes the size of the farm, membership of the Onion Farmers Association, and how the land is cultivated.

Sampling techniques and sample size**:** The study used snowballing and simple random sampling techniques. Snowballing was used to identify 321 onion farm households in nine farming communities in the Wukari Local Government Area. The farming communities were: Arufu, Akwana, Chembe, Ndo-Katwsen, Tor-Sai, Tsokwa-Kaso, Bye-Pyi, Ndo-Idi, and Wukari. Sample size was computed using Yamane (1967), as cited in Kara et al. (2019). The formula is specified as:

$$n = \frac{N}{1+N(e)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: n = sample size

N = population size

e = margin of error at 5% (0.05)^2

Thus, $n = \frac{321}{1+321\,(0.05)2} = 178$

The study increases the sample size by 20% to account for contingencies such as irretrievable questionnaire.

Thus: $\frac{20}{100} \times 178 = 35.6 \approx 36$

Thirty-six questionnaires were added to the original 178, increasing the sample size to 214, and the 214 respondents were then randomly selected from the nine communities based on the percentage of farm households in each community (Table 1). The sampling procedure agrees with Onya (2021).

Table 2. Sample design outlay for the study area.

Onion farming communities	Population	Sample size	Addition
Arufu	167	92	19
Akwana	26	14	03
Chembe	12	07	01
Ndo-Katswen	15	08	02
Tor-Sai	28	16	03
Tsokwa-Kaso	16	09	02
Bye-Pyi	18	10	02
Ndo-Idi	10	06	01
Wukari	29	16	03
Total	321	178	36

Source: Field survey data, 2023

***Analytical techniques*:** The analytical techniques used were descriptive statistics and the Cobb-Douglas stochastic frontier production model.

***Model specification*:** The Cobb-Douglas frontier production function used in the study is explicitly specified as:

$$Ln\ Y_{ij} = \beta_0 + \beta_1 lnX_{1ij} + \beta_2 lnX_{2ij} + \beta_3 lnX_{3ij} + \beta_4 lnX_{4ij} + V_{ij} - U_{ij} \ldots. (2)$$

Where: $Ln =$ the natural logarithm to base e

$Y_i =$ output of onion from farm i measured in kilogram per hectare (Kg/ha)

β_0 = constant term,

β_1- β_4 = Maximum Likelihood Estimate (MLE) coefficients, and

X_1 = Quantity of Seed (kg/ha)

X_2 = Fertilizer (kg/ha);

X_3 = Agrochemicals (in lit/ha);

X_4 = Labour (in man day/ha)

V_i = Statistically disturbance term such as measurement error and external sources out of the farmer's control.

$$U_{ij} = \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where; U_{ij} = Technical inefficiency of the ith farmer

δ_1-δ_7 = Parameters to be estimated

Z_1 = Age of the farmers (years),

Z_2 = Household size (number of persons in household),

Z_3= Educational level (Never been to school =0, primary=1, secondary = 2, Diploma =3, Degree and above = 4)

Z_4 = Farming experience (years),

Z_5 = Extension contacts (No contact with extension agent = 0, had contact = 1)

Z_6 = Farm size (Hectares)

Z_7 = Land cultivation technique (Manual ploughing =0, otherwise =1)

The *a priori* expectation was that the coefficients of the efficiency inputs (X_1 to X_4) which are β_1, β_2, β_3, and β_4 should be positive (i.e., greater than zero). The coefficients of the independent variables of the inefficiency inputs (Z_1 to Z_7) should be negative (i.e., less than zero), which indicates a reduction in technical inefficiency and vice versa. The Maximum Likelihood Estimates (MLE) and the technical efficiency estimates were simultaneously estimated using the computer program FRONTIER version 4.1 (Coelli, 2005).

RESULTS AND DISCUSSION

***Summary statistics of the output and input variables*:** The statistics for variables generated from the survey are reported in Table 2. The average onion output of the survey farms was 5,282 kilograms per hectare (kg/ha), or approximately 5.30 tons per hectare (t/ha), with minimum and maximum production of 1.98 t/ha and 9.24t /ha, respectively. However, the variability of the mean stood at 1.68 t/ha. On average, the quantity of seed used was 4.7 kg/ha, with a minimum and maximum of 2.3 kg/ha and 7.6 kg/ha, respectively. The standard deviation was 1.3 kg/ha. The average fertilizer used in the study area was 216 kg/ha with a minimum of 133 kg/ha and a maximum of 361 kg/ha, respectively. The variation in the use of fertilizer stood at 69.5 kg/ha. The average quantity of agrochemicals used by farmers in the study area was 1.2 liters per hectare (l/ha) with a minimum of 0.6 l/ha and a maximum of 2.7 l/ha. The standard deviation was 0.3 l/ha. The average labour work was 48 man-days per hectare with a minimum of 27 man-days per hectare and a maximum of 57 man-days of work per hectare.

Table 3. Summary statistics of output and inputs variables.

Variable	Unit	Mean	Min.	Max.	Std. dev.
Output					
Onion	Kg/ha	5282	1980.8	9243.5	1680.8
Inputs					
Seed	Kg/ha	4.7	2.3	7.6	1.3
Fertilizer	Kg/ha	216	133	361	69.5
Agrochemicals	Lt/ha	1.2	0.6	2.7	0.3
Labour	Manday/ha	48	27	57	13.3

Source: Field survey data, 2023

***Summary statistics of the socioeconomic characteristics of the respondents*:** The statistics of the respondents' socioeconomic characteristics is presented in Table 3. The mean age of the farmers was 41 years, with a minimum age of 18 and a maximum age of 65 years. The age variability was

10.3 years. The result implies that the farmers in the study area are young and energetic. This is important because, as youth, they may be willing to assume greater risk in anticipation of profit than the older or much younger ones. The result agrees with Yidau et al. (2020). The result in Table 3 also shows the mean household size of the respondents is 8 persons with the minimum of 2 and maximum of 21 persons. This implies that there was a reasonable supply of family labour for farm operations in the study area as most respondents have relatively large families. This result conforms the findings of Yidau et al. (2020).

Table 3 further revealed that 21.3% of the respondents had never been to school, 14.6% attained primary school, 27.0% attained secondary school, 26.4% had Diploma/NCE, and 10.7% had degrees and above. This implies that majority (78.7%) of the respondents had some form of formal education. It means that their levels of education will expose them and also help them in effective communication and adoption of new innovations which could lead to increased output compared to those without formal education. This agrees with the work of Akanlik (2020).

Table 4. Socio-economic characteristics of the respondents.

Variable	Freq.	Percent	Mean	Min.	Max.	Std. Dev.
Age			41	18	65	10.3
Household size			8	2	21	3.2
Educational level						
Never been to school	38	21.3				
Primary school	26	14.6				
Secondary school	48	27.0				
Diploma/NCE	47	26.4				
Degree & above	19	10.7				
Farming experience			15.7	1.2	32.0	5.1
Extension contacts						
No	159	89.3				
Yes	19	10.7				
Farm size			1.43	0.52	4.7	0.29
Cultivation method						
Manual	155	78.3				
Machine	23	21.7				
Total	178	100				

Source: Field survey data, 2023

Also, the result in Table 3 revealed that the average farming experience of the farmers was 15.7 years, with a minimum experience of 1.2 and a maximum experience of 32 years. The experience variability was 5.1 years (Table 3). It is thus, reasonable to deduce that farmers in the study area are well experienced in onion farming and portray good signal for higher productivity. The result agrees with the work of Berhan (2015). Furthermore, the result in Table 3 indicates that majority (89.4%) of the respondents had no contact with extension agents. This may have a negative effect on the adoption of improved onion production technologies. The result of this finding disagreed with the work of Umaru and Maurice (2019). Table 3 shows that the mean farm size cultivated by the respondents in the study area was 1.43 hectares of land with a minimum of 0.52 hectare and maximum of 4.7 hectares. The result shows that the farmers in the study area are small-scale farmers. The small-scale onion cultivation may constrain the quantity of farmers' output. The result agrees with the work of Yidau et al. (2020). The results in Table 3 revealed that majority (78.3%) of the respondents cultivate their farmland manually using crude implements while 21.7% used machines. The farmers may not be efficient in land cultivation operation because of manual operation and the used of crude implement.

***Diagnostic statistics of variance parameters of the stochastic frontier production function*:** The discussion of the diagnostic statistics is based on the estimated parameters of the Cobb-Douglas stochastic frontier production function (Table 4). From the estimates of the stochastic frontier production, the variance parameters sigma square ($\delta^2=\delta v^2+\delta u^2$), and lambda ($\lambda = \frac{\delta u}{\delta v}$) are 0.0104083 and 1.885084 respectively and are different from zero, thus indicates a good fit of the model and the correctness of the specified distributional assumptions. The lambda value is greater than zero further indicate that the variation in the observed output from the frontier output is due to technical inefficiency and random noise. The result further shows that the change in the onion output explained by technical inefficiency is relatively greater than the changes in the onion output explained by the pure noise component of the composed error term. Gamma$\left(\Upsilon= \frac{\lambda^2}{1+\lambda^2}\right)$is a parameter in the variance parameters that indicates a measure of the level of inefficiency in the variance parameter and is estimated to be 0.78039. This implies that 78% of the total variations in the onion output in the study area were due to technical inefficiency. The estimated coefficient in Table 4 agrees with the findings of Baree (2012).

The maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production function are presented in Table 4. The coefficients of estimated parameters ($\beta_1\beta_2\beta_3\beta_4$) in the Cobb-Douglas stochastic production function are directly interpreted as measures of production elasticity. Therefore, the discussion of parameters was done based on output elasticity. The elasticity of onion output with respect to the various inputs used is a measure of the resource productivity of the onion farmers. The output elasticity indicates the degree of responsiveness of onion output to changes in the various input variables. The sum of the partial elasticity of the various input variables with respect to output is a measure of the return to scale of the onion farms.

The stochastic frontier model parameters in Table 4 revealed that all of the output elasticities are positive. The positive sign means that as the input increases, output increases, and the

negative sign indicates that as the input increases, output decreases. The output elasticities for seed, fertilizer, agrochemicals, and labour are 0.4552, 0.2751, 0.2097, and 0.2309. The implication of this is that seed has the highest contribution to onion production, followed by fertilizer, labour, and finally agrochemicals. The result simply means that a one-unit increase in seed employed per hectare, holding all other factors constant, will increase onion yield by 0.4552. Also, a unit increase in fertilizer employed per hectare will increase onion output by 0.2751. Similarly increasing the use of agrochemicals by one unit, onion output will increase by 0.2097 and every unit increase in labour used increases onion yield by 0.2309 respectively. The rate of return to scale was 1.171, implying that when all inputs are jointly increased by 1%, onion output will increase by 1.171%. The result is in agreement with the work of Akanlik (2020), Sunday & Monday (2021).

Table 5. Maximum likelihood estimates for parameters of the Cobb-Douglas stochastic frontier production model.

Variable	Parameter	Coefficient	Std. error	P-value
Constant	β_o	0.8279***	0.09935	0.000
Seed	β_1	0.4552***	0.12379	0.000
Fertilizer	β_2	0.2751***	0.06613	0.000
Agro-chemicals	β_3	0.2098***	0.04064	0.000
Labour	β_4	0.2309***	0.06666	0.000
Inefficiency effects				
Age	δ_1	0.0245	0.02290	0.284
Household size	δ_2	-0.0787**	0.03850	0.041
Education level	δ_3	-0.1168*	0.06170	0.059
Farming experience	δ_4	-0.0015**	0.00071	0.034
Extension contacts	δ_5	0.5500	0.63118	0.384
Farm size	δ_6	-0.0777	0.12410	0.532
Land cult. technique	δ_7	-0.0695	0.29347	0.813
Variance parameters				
Sigma-square (u)		0.0901	0.01523	
Sigma-square (v)		0.0478	0.00850	
Lambda ($\lambda=\delta^2_u/\delta^2_v$)		1.8851	0.02264	
Sigma^2 ($\delta^2=\delta^2_v+\delta^2_u$)		0.0104	0.00214	
Gamma ($\Upsilon=\lambda^2/1+\lambda^2$)		0.7804		

Source: Field survey data, 2023. Note: *** denote significance at 1%

***Inefficiency production model estimates*:** The inefficiency parameters were specified as age, household size, education level, farming experience, extension contact, farm size, and land cultivation technique. Five out of seven variables used in the model have a priori expected signs, and three of the variables were statistically significant. A negative coefficient indicates that the variable increases efficiency (reduces inefficiency) in the onion production, and vice versa.

The estimate of household size is statistically significant at five percent probability level (Table 4). The result implies that household size of the respondents is reducing their technical inefficiency reasonably. This is true because the availability of labour to carry out crop husbandry activities in a timely manner may increase efficiency and reduce inefficiency. The result agrees with Ndanitsa et al. (2021). The coefficient of education was negative and statistically significant at the 10% probability level. This implies that the estimated level of education is significantly reducing the technical inefficiency level of onion farmers in the study area. A higher level of education increases the chances of using improved technology and techniques, which may reduce technical inefficiency and increase efficiency. The result in Table 4 shows that the estimate of farming experience was found to be negatively related to inefficiency and statistically significant at a 5% probability level. This implies that farmers experience in the study area is very important in reducing inefficiency. This may be through because a farmer who has been growing onion for many years is likely to be knowledgeable about the pattern of rainfall, the incidence of pest and diseases, and other agronomic conditions of the area than a farmer who is just coming into the business irrespective of their level of education. The findings agree with Umaru and Maurice (2019).

***Technical efficiency estimates*:** The average farm-level technical efficiency of onion farmers was predicted for the stochastic frontier model and presented in Table 5. The mean technical efficiency is approximately 0.8609, implying that the average farmer produced only 86 percent of the maximum attainable output for a given level of input for the period of production under analysis. It also implies that there is still 14 percent potential for increasing the output of Decision-Making Units (DMUs) simply by adopting the technology of best-practice DMUs. The highest estimated technical efficiency is 0.9858, and the lowest is 0.5066. In the present study, the majority (88.2%) of the sampled farmers have a technical efficiency level greater than 80% but less than 100% (Table 5). The result of the finding agrees with Ndanitsa et al. (2021).

Table 6. Technical efficiency distribution of farmers in the study area, Cobb-Douglas model.

Efficiency scores	Frequency	Percentage
1.00	0	0.00
>0.90<1	86	48.3
>0.80≤0.90	71	39.9
>0.70≤0.80	13	7.3
>0.60≤0.70	3	1.7
>0.50≤0.60	5	2.8
Total	178	100
Mean	0.8609	
Minimum	0.5066	
Maximum	0.9858	
Std Dev.	0.0642	

Source: Field survey data, 2023.

***Conclusion*:** According to the study's findings, the technical efficiency of the onion growers in the studied area was below the production of the frontier. On average, the respondents were able to obtain almost 86% of optimal output from a mix of production inputs, according to the mean technical efficiency of 0.8606. This indicates that there is potential to raise farmers' technical efficiency by 14% in the near future. Technical efficiency varied among the farms in the study area. The technical efficiency of the lowest farm was 0.50 (50%), while the greatest farm had a technical efficiency of 0.98 (98%). In the study area, the characteristics that significantly increased technical efficiency were the input factors (seed, fertilizer, agrochemicals and labour) and those that decreased technical inefficiency were household size, educational attainment, and farming experience. Therefore, the study recommends that the government and non-governmental organizations should subsidize the cost of farming inputs, farmers should be encouraged to improve educational attainment, and they should utilize their extensive experience to involve family members in onion farming to mitigate the high costs associated with hired labour.

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***Policy referred*:** Agricultural Promotion Policy (APP) 2016-2020; National Food Security Policy.

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